# Executive Summary

*Background*

Images are an important part of biomedical knowledge. Pictures facilitate the understanding of biological structure and function, and are an essential component of education, research, and health care delivery. New computer-based technologies are providing an unprecedented opportunity to supplement the traditional two dimensional images of medicine, such as pictures in textbooks and plain radiographs, with dynamic three dimensional images. These images can be viewed, rotated, and reversibly dissected in a manner analogous to the physical objects they represent, providing valuable instruction to the student, insight to the researcher, and critical treatment planning information to the practitioner.

The National Library of Medicine (NLM) has long been a world leader in the archiving and distribution of the print-based images of biology and medicine. NLM has also been a pioneer in the use of computer systems to encode and distribute the textual knowledge of the life sciences. The NLM's Long Range Planning effort of 1985-86 foresaw a coming era where NLM's bibliographic and factual database services would be complemented by libraries of digital images, distributed over high speed computer networks and by high capacity physical media. This planning panel was convened to recommend when and how the NLM might proceed in the development of such digital image libraries.

*Findings*

Acquiring and providing access to digital image libraries is entirely consistent with NLM's institutional mandate to acquire, organize, and make available the knowledge of biology and medicine.

The technologies underlying the computer-based representation and display of complex three dimensional biological structure are sufficiently mature that the NLM can proceed with the building of prototype digital image libraries.

The digital image requirements of education, research and clinical practice differ from one another. Education may profitably employ established teaching collections of representative normals and abnormals. Research requires laboratory tools which empower an investigator to make and test hypotheses based on numerical, conceptual and image data, to share that data easily with collaborators, and contribute it to

shared national resources when appropriate. Clinical practice imaging is often focussed on the diagnostic and treatment planning considerations for a single patient, and uses images representing that patient's unique condition.

There remain fundamental research problems in the domain of computerized representation of biomedical structural data, and its linkage to related text and numeric data. Additional research support is needed to facilitate progress in this emerging subdiscipline of medical informatics.

NLM connection to and use of high speed computer networks is an essential prerequisite for the efficient distribution of computer-based digital images.

*Recommendations*

The panel makes five principal recommendations:

1. NLM should undertake a first project, building a digital image library of volumetric data representing a complete normal adult human male and female. This "Visible Human" project would include digital images derived from computerized tomography, magnetic resonance imaging, and photographic images from cryosectioning of cadavers. A working group should be assembled from experts in anatomy, clinical imaging, and computer science to establish standards for acquisition, and computer representation of the data. Technical guidelines for this phased project are offered. The panel views this project as a cornerstone for a future set of related image libraries, and a test platform for developing methods and standards.

2. The NLM should support a follow-on research effort to develop methods, tools and standards for classification of anatomic image data from the Visible Human Project, so that applications may be developed which can extract, manipulate and display image subsets on the basis of organs, tissues, body systems and biologic function.

3. NLM should expand upon initial image libraries composed of normal structure to encompass specialized image collections which represent related structural information, such as embryological development, normal and abnormal variations, and disease-related images. In this regard, NLM should collaborate with appropriate professional societies and other organizations to identify

and pursue worthy examples of specialized image collections which have been developed by subject experts.

4. NLM should encourage and support investigator-initiated research into methods for representing and linking spatial and textual information (and other relevant datatypes), and support efforts to introduce computer reconstructed anatomical imaging technologies into health professions curricula nationwide.

5. The NLM should develop and enhance its wide area computer network connections to provide an efficient electronic distribution mechanism for large digital files such as those encoding biomedical images. In the development phase of imaging projects, NLM should continue and enhance its connectivity to NSFnet and the research Internet. NLM should consider developing image-based applications which make use of the proposed gigabit speed National Research Network.

*Resources*

In the short term, the costs of undertaking the data acquisition phase of the Visible Human project can be derived from existing technologies and similar projects undertaken on a smaller scale. The panel estimates that Phase I of this project would require approximately $1 million and yield a uniquely valuable image data set.

Phase II of the Visible Human Project--the classification of the image data--is considerably more labor and time intensive if undertaken using current manual or semi-automated methods, such as contour tracing by skilled anatomists. Between 40 and 50 man-years of effort would be required, at a cost of approximately $5 million, to fully classify the anatomic data.

Research to develop new methods for representing and linking structural and symbolic data in the life sciences would benefit greatly from support for 5-10 high quality investigator-initiated grants annually at an estimated annual cost of $3 million.

NLM connection to high speed computer networks is an extension of its current connections to NSFnet and the research Internet through the Lister Hill Center. The panel believes that over the next several years incremental improvement in bandwidth should be available to the NLM at approximately the same costs as it now bears (approximately $100,000 per year). Experimental projects involving commercial telecommunications networks should be pursued under collaborative cost-sharing agreements.